THE DUAL PROCESS THEORY OF AUTISM

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To appear in:
K. Morsanyi & R. Byrne (Eds.), *Thinking and Reasoning in Autism, Psychology* Press/Routledge series on Current Issues in Thinking and Reasoning.

Autism Spectrum Disorder (ASD)

Autism Spectrum Disorder (ASD) is characterised by difficulties in social communication and interaction alongside repetitive and stereotyped behaviours, interest and activities (APA, 2013). We use the terms ‘autism’ and ‘autistic people’ throughout this chapter, in-line with recommendations from the autistic community (Kenny et al., 2016). Recent reports concerning prevalence rates provide estimates of up to one in 59 children having autism (Baio et al., 2018), and autism is reported to cost the US government $175 billion per year (£32 billion per year in the UK). This is more than any other medical condition and greater than the cost of cancer, strokes and heart disease combined, highlighting the impact of autism in society and the need for a better understanding about how to support autistic people to reach their full potential (Buescher et al., 2014). The criteria for diagnosing autism includes a lack of intuitively understanding nuances and rules within social interactions and communication, alongside excessively circumscribed interests involving perseverative behaviour pursuing specific restricted topics (APA, 2013). An interesting aspect of autism is that it is not only associated with deficits, but that it can also involve strengths in other areas, and in some cases, talent in certain ‘islets of ability’ (Baron-Cohen et al., 2009; Happé & Vital, 2009). The weaknesses in autism have been characterised as generally pertaining to areas of social functioning, and the strengths to areas of non-social functioning. Thus, autistic people can have both relative weaknesses and strengths within different domains, making it a paradoxical condition (Baron-Cohen et al., 2011).

Single factor theories of autism

There are a number of key psychological theories about autism, most of which focus on one specific process or domain. The enhanced perceptual functioning theories (Plaisted et al., 2006; Mottron et al., 2006) emphasise greater attention to detail in autism, based on findings from visual search tasks where autistic people show faster detection of local-level targets compared to controls (O'Riordan et al, 2001; Plaisted et al., 1998), and in the embedded figures task where autistic people are faster than controls to find simple target shapes within complex figures (Jollife et al., 1997). The weak central coherence theory (Frith, 1989; Happe & Frith, 2006) focuses on reduced ability for holistic processing in autism, such as deficits in face-processing, which require processing the features in a holistic manner for identification and emotion recognition. The weak central coherence theory can also help explain the greater local processing in autism, as reduced holistic processing may produce a greater reliance on featural processing (or vice versa). Another theory of autism is the executive dysfunction theory (Ozonoff et al., 1990; Russell, 1997), which proposes that deficits in executive function underlie the difficulties seen in autism. The mindblindness theory proposes that people with autism have difficulties in having a theory of mind about others (Baron-Cohen, 1990, 1995; Baron-Cohen et al., 1985), which involves the ability to understand the mental states of others and to predict and understand their behaviour based on it (Premack & Woodruff, 1978). There is a wealth of evidence for deficits in theory of mind in autism, which has been reported across both children and adults (Baron-Cohen et al., 1993, 2000, 2013).

Dual factor theories of autism

But limitations of all these theories have been raised, including that they largely account for either the social or the non-social characteristics of autism, but have difficulties accounting for both. Further psychological theories of autism have been developed which involve two separate mechanisms, in order to try and better account for both the strengths and weaknesses often found in autism. One mechanism is generally related to the social weaknesses and another one related to the non-social strengths. For example, one popular two-factor framework is the Empathising-Systemising model, which then also relates to the extreme male brain theory of autism (Baron-Cohen, 2002, 2003, 2009, Baron-Cohen et al., 2011). Within the empathising-systemising theory, empathising involves the drive to understand the social world, while systemising involves the drive to understand the non-social world. Empathising includes recognising the emotions in others and responding to them with appropriate behaviour, as well as more cognitive abilities such as reading the mental states of others. Systemising, on the other hand, includes processes commonly seen as strengths in autism, such as greater attention to detail and more logical thinking. Research has shown that females generally do better at measures of empathising compared to males (Auyeung et al., 2009; Baron-Cohen, 2003; Baron-Cohen & Wheelwright, 2003), such as being able to read the mental states of others from images of people's eye regions (Baron-Cohen et al., 2001). In contrast, males generally do better at measures of systemising than females (Baron-Cohen et al., 2004; Lawson et al., 2004), such as being able to more quickly spot smaller shapes within more complex figures on the embedded figures task (Jolliffe et al., 1997). Together, this theory proposes that females are more likely than males to have a cognitive profile where their empathising ability is higher than their systemising ability, while males are more likely to have a cognitive profile where their systemising ability is higher than their empathising ability.

According to the extreme male brain theory, autism is characterised as an extreme of the empathising-systemising pattern typically seen in males, with very poor empathising alongside intact, or even enhanced, systemising ability compared to typical males and females (Baron-Cohen, 2003, 2009; Baron-Cohen et al., 2005). Evidence has shown impaired empathising and intact, or enhanced, systemising compared to controls across both questionnaire and behavioural assessments (Baron-Cohen, 2003, 2009; Baron-Cohen et al., 2001, 2004; Lawson et al., 2004). Therefore, autism is theorised to reside at the extreme end of a wider continuum of 'autistic-like traits', which are continuously distributed across the general population (Constantino & Todd, 2003; Plomin, Haworth & Davis, 2009; Posserud, Lundervold & Gillberg, 2006; Wing, 1988). Consistent with this idea of a continuum of autistic-like traits, Ruzich et al. (2015) report that males have higher levels of autistic-like traits than females within the general population, and those with autism have significantly higher autistic-like traits than males from the general population (with no sex differences within the autism population).

A similar two-factor model to the Empathising-Systemising and extreme male brain theories was proposed by Badcock & Crespi (2008), which involves the two factors of mentalistic and mechanistic processing. Mentalistic processing involves the ability to process about people, while mechanistic processing involves the ability to process about 'things'. The theory proposes there are different cognitive continuums for each of these factors, ranging from poor to high ability within each process. The relationship between these two factors in people is proposed to be related to two extreme profiles associated with different disorders, with one end characterised by hypo-mentalistic processing alongside hyper-mechanistic processing, and the other end characterised by hypo-mentalistic processing alongside hyper-mechanistic processing. Similar to the extreme male brain theory, the end of the continuum defined by hyper-mechanistic/hypo-mentalistic processing is associated with autism. The other end of the continuum characterised by hyper-mentalistic/hypo-mechanistic processing is associated with psychosis, leading to an autism-psychosis spectrum model. While there is a wealth of research showing difficulties in mentalistic types of processing and strengths in mechanistic processing in autism, there has been limited research about the other end of the continuum that Crespi & Badcock (2008) associate with psychosis, which in the Empathising-Systemising framework would be termed the 'extreme female brain'. Research has explored whether the extreme female brain might relate to a profile with greater empathising and reduced systemising (i.e. the opposite pattern to autism and the extreme male brain as predicted by the Empathising-Systemising theory. Brosnan et al. (2010) reported that a cognitive profile defined by higher empathising relative to systemising (i.e. hyper-mentalistic profile) was related to greater self-reported levels of psychosis in a non-clinical female population. Further research has found that autistic people who had experienced psychosis have higher empathising relative to systemising when compared to autistic people without psychosis experiences (Larson et al., 2015). While these initial findings are consistent with the autism-psychosis model as a cognitive continuum, there has been a dearth of research investigating reasoning ability related to these two-factor models.

Initial reasoning research

Our initial research investigating reasoning and decision-making related to the two factor theories examined the opposite end of the proposed cognitive continuum to autism, attempting to link the reasoning profile consistently seen in psychosis to measures of empathising/systemising, in order to test predictions of the autism-psychosis model. One of the most consistent findings in psychosis is a jumping to conclusions reasoning bias, which is reported in half or more of clinical people with delusions (Freeman, 2007; Langdon et al., 2008). One commonly used paradigm to index jumping to conclusions is the beads task. In a classic version of the beads task, the participant is presented with 2 jars of beads which have different ratios of different coloured beads within them, with one jar typically having 80% white beads and 20% black beads and the other jar having 20% white beads and 80% black beads. The jars are then covered up and beads are drawn one at a time from one of the two jars. The participants' role in the task is to identify which jar they think the beads are being drawn from. The key variable being measured is how many beads are requested before the participant feels able to make their decision. A jumping to conclusions bias is evidenced when a decision is made after seeing only one or two of the drawn beads.

We ran a study to test whether a jumping to conclusions reasoning bias characteristic of psychosis might be related to a cognitive pattern involving greater mentalistic/empathising processing alongside low mechanistic/systemising processing, consistent with the idea of the extreme female brain (Brosnan, Ashwin & Gamble, 2013). For that study we recruited 218 non-clinical adolescents and adults (48M; mean age = 27.4) without a psychiatric diagnosis and used a computerised version of the beads task to measure the jumping to conclusions bias. We also included the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2003) as a self-report measure of empathising/mentalistic processing, and both the self-report Systemising Quotient (SQ; Baron-Cohen et al., 2003) and the behavioural embedded figures task as measures of systemising/mechanistic processing. The SQ scores were subtracted from the EQ scores in order to produce an Empathising Bias score for each participant, with higher scores reflecting greater empathising relative to systemising ability. Participants were classified as showing a jumping to conclusions bias if they made a decision about which jar the beads were coming from based on drawing only 1 or 2 beads (n = 68; mean number of beads requested = 1.27), and participants who made choices based on more than 1 or 2 beads drawn were classified as non-jumping to conclusions (n = 155; mean number of beads requested = 7.18). Results of the study showed that the jumping to conclusions group had higher Empathising Bias scores compared to the non-jumping to conclusions group, revealing a cognitive profile where those who show a jumping to conclusions bias are characterised by greater empathising compared to systemising. These results are in-line with ideas that enhanced empathising/mentalistic relative to systemising/mechanistic processing relates to the reasoning bias consistently reported in psychosis. Additionally, the jumping to conclusions group made significantly more errors on the embedded figures test compared to the non-jumping to conclusions group, showing that a jumping to conclusions reasoning bias relates to reduced attention to detail. Since attention to detail is a trait associated with systemising/mechanistic ability (Brosnan et al. 2012), the results further show that a jumping to conclusions bias relates to reduced systemising/mechanistic ability. Together, these findings are consistent with the predictions from the autism-psychosis model that a cognitive profile characterised by hyper-mentalising relative to lower mechanistic processing relates to a jumping to conclusions reasoning bias consistently seen in psychosis.

The findings from that initial study of reasoning were consistent with the ideas of the two-factor models and the extreme female brain theory, with those people showing a bias with higher empathising scores relative to systemising scores jumping to conclusions more than those displaying the opposite cognitive pattern. The extreme male brain theory would predict those with autism should show the opposite reasoning profile to that, with a tendency to reason longer towards making a decision in the beads task. While there has been much research investigating false belief reasoning in those with autism to date, which relates to understanding the mental states of others and has generally shown deficits and delays in the development of false belief understanding in autism (Baron-Cohen et al., 1993, 2000, 2013), there has been little research exploring non-social reasoning in autism. This is surprising given the importance of general reasoning to everyday human functioning. As Holyoak and Morrison (2012: p. 1) stated: “Every fully functioning human adult shares a sense that the ability to think, to reason, is a part of their fundamental identity.” If the ideas of the two factor theories of cognition above could be utilised to help study reasoning and decision making processes, this may help to better characterise and understand the cognitive profile of autism. Based on our initial findings (Brosnan et al., 2013) and the two-factor cognitive theories outlined above, we predicted for the first time that the opposite reasoning bias which is typically reported in psychosis would be evident in autism.

Initial reasoning research in autism

We tested this idea in a group of 20 adolescents with autism (19M; mean age = 14.6) and a group of 23 adolescents without autism (15M; mean age = 14.4) recruited as a control group (Brosnan, Chapman & Ashwin, 2013). We measured reasoning using the same computerised version of the beads task in the study described above (Brosnan et al., 2013), as well as a measure of systemising/mechanistic ability and a short form of the social responsiveness scale as a measure of autistic-like traits (SRS-short; Kanne et al., 2009). The autism group had higher autistic-like trait scores compared to the control group, consistent with them having a diagnosis of autism. Since differences in the number of beads required to make a decision could relate to how confident people are about their choice, once participants made a decision they were also asked about how confident they were about their decision. Results in the beads task revealed the autistic group actually required a significantly larger number of beads compared to the controls in order to make their decision about which jar they thought the beads were being drawn from, demonstrating a more circumspect reasoning bias (Brosnan et al., 2013). The greater requests for beads was not due to differences in confidence in those with autism, as the groups did not differ in their confidence level about their choice. Further results showed that a greater number of beads drawn before a decision was positively correlated with the measure of systemising/ mechanistic ability, linking this factor of autism with drawing more beads before making a decision. Together, these results showed a more circumspect reasoning style in autism, where the autism group gathered more data before making a decision.

Reasoning in autism

Our initial research therefore indicated that reasoning in autism could be characterised by greater systemising/mechanistic reasoning ability, relative to empathising/mentalising ability. These findings are consistent with previous neuropsychology research using batteries of tests in different domains and reporting reasoning and decision-making difficulties in autistic children and adults in comparison to control groups (Goldstein et al., 2001; Minshew et al., 1997; Williams et al., 2006). In addition, difficulties and delays in making decisions by autistic people have been reported in research involving observations made by parents and teachers (Johnson et al., 2006; Winter, 2003). Adults on the autism spectrum are reported to have greater difficulties in making everyday decisions (e.g. when to go to bed, what clothes to wear, what to eat etc.) and to make more bad decisions (e.g. purchasing items that were never used, being late on rent payments etc.) compared to control adults (Gaeth et al., 2016; Levin et al., 2018). A self-report study by Luke et al. (2012) found three core areas of difficulty within reasoning and decision-making for people with autism; (1) when it involved talking to others; (2) when it involved a change in routine; and (3) when decisions had to be made quickly. Whilst the first two relate to the diagnostic criteria for autism, the third issue suggests difficulties with rapid processing specifically. Autistic people are also reported to be less susceptible to reasoning biases than the general population. One example involves the classic framing effect, where people's decisions between two options depends on how the choices are worded and presented (Tversky & Kahneman, 1981). For example, when participants are shown an amount of money, their decision about how to gamble with the money is determined by whether its framed in terms of the loss or gain in money within the situation (e.g. people are more likely to gamble when the option is framed in terms of money lost rather than when its framed in terms of money gained). People with autism are reported to show a reduced framing effect bias in terms of using contextual information towards decisions (De Martino et al., 2008; Shah et al. 2016), which has been interpreted as showing a reduced integration of emotional information into the decision process alongside a greater logical and rational decision-making style.

A study by Mosanyi et al. (2010) examined reasoning heuristics in autism using the conjunction fallacy, which happens when people mistakenly assign a higher probability for two events co-occurring compared to either of the events occurring on their own. This is incorrect because the likelihood of two independent events occurring at the same time, or in conjunction, should be less than or equal to the probability of either event occurring alone. For example, in the Linda problem which is commonly used to test the conjunction fallacy, a description about Linda is provided that includes statements about her being a smart and outspoken woman who majored in philosophy and is concerned about social justice and discrimination and who participates in demonstrations etc. Participants are then asked to judge some statements about Linda based on how likely they believe them to be, with people often believing the statement ‘‘Linda is a bank teller and is active in the feminist movement’’ to be more likely compared to the statement ‘‘Linda is a bank teller.’’ Despite the fact that the likelihood of both events being true about Linda is less than the likelihood for the one event being true, yet people still choose the statement with both events because they activate beliefs about Linda from her statement. These beliefs are hard to inhibit when making judgments about her. Mosanyi et al (2010) found that autistic adolescents were less likely than controls to commit the conjunction fallacy and so were less biased in their judgements. While the results showed reduced bias in the autism group, which is typically interpreted as intuitive processing, their results also showed those with autism were not more rationale in their choices compared to controls. The paradigm could separate intuitive and rationale choices, and group differences were evident in biased responses but not in rationale choices. Thus, the findings were not completely consistent with some of the evidence reported in the studies above. But taken all together, the findings suggest the reasoning profile in autism may be characterised by a lack of the reasoning biases which are typically exhibited by those in the general population, along with difficulties in rapid processing towards decision-making. This profile can be best described with the theoretical framework of Dual Process theories, although not all the results across various reasoning studies in autism have been consistent with each other to date.

Dual Process theories

Dual Process theories are a set of similar theories which provide a framework for human reasoning ability and which have been dominant within cognitive psychology for almost 50 years (Evans & Frankish, 2009). The various Dual Process theories involve a common proposal of two separate types of thinking and reasoning processes, which have been termed ‘Type 1’ and ‘Type 2’ processing to denote the difficulty of applying a linguistic label to them. ‘Type 1’ processing (which is also termed ‘intuitive’ processing) commonly includes such characteristics as being autonomous, rapid, effortless, parallel, non-conscious and independent of working memory and other higher cognitive ability. ‘Type 2’ processing (also termed ‘deliberative’ processing) involves slower, effortful, sequential, conscious mechanisms and is heavily dependent on working memory and individual differences in general cognitive ability. The dual processes of Type 1 and Type 2 processing will be referred to throughout this chapter as intuition and deliberation (respectively) for convenience, because these terms are generally more familiar to people. Intuitive processes are assumed to yield default responses in most situations, unless they are intervened upon by distinctive higher order deliberative processes. This idea that intuitive processes are the default response and they precede deliberative processing is known as the ‘default-interventionist position’ (Evans & Stanovich 2013; Kahneman 2011). Although not all the evidence is consistent with these ideas (see the discussion section for further information about this and other critical points).

Reasoning measures

One of the most widely used behavioural assessments of intuition and deliberation is the Cognitive Reflections Test (CRT: Frederick, 2005). The CRT comprises of reasoning questions which have both an intuitive (incorrect) and a deliberative (correct) response. An example question is "A bat and a ball cost £1.10 in total. The bat costs a pound more than the ball. How much does the ball cost?" Most people tend to provide the intuitive answer which is 10 pence, however this response is not actually correct. Instead, the correct answer is 5 pence. People typically provide a majority of intuitive responses to the CRT, which are actually incorrect, even when participants are comprised of students at Ivy League universities in the USA (Frederick, 2005). This preference for intuitive responding is theorised to reflect the output from initial intuitive reasoning which has not been over-ridden by deliberative processing. The over-riding of initial intuitive processing by subsequent deliberative processing is demonstrated by achieving the correct answer. In support of this, experimental manipulations designed to encourage participants to engage in deliberative processing reduces intuitive responses (Evans & Curtis-Holmes, 2005).

The propensity to engage in intuitive and deliberative processing can also be assessed through self-report. The Rational-Experiential Inventory (REI) is a widely used 40 item self-report questionnaire of intuition and deliberation (Epstein et al., 1996). The Rational component is used to index deliberative reasoning and contains 20 items that are based upon a 'need for cognition' (Cacioppo & Petty, 1982), which measures engagement and enjoyment of cognitive activities. The Experiential component is used to index intuition and includes 20 items developed to measure engagement and confidence in one's intuitive abilities (Epstein et al., 1996; Pacini & Epstein, 1999). The items are scored on a 5-point scale ranging from 1 (completely false) to 5 (completely true). An example item from the experiential/intuitive scale is; ''I often go on my instincts when deciding on a course of action'', while an example item from the deliberative scale is; ''I have a logical mind''. Epstein et al. (1996) argue that these two information processing styles are independent of one another, such that one can be high or low in either or both dimension. Singleton et al. (2018) found that a behavioural test of logical thinking was best predicted by the self-report deliberation subscale of the REI, but not the intuition subscale of the REI nor self-reported scores in systemising. Freeman et al. (2012) also found that combinations of high intuition with low deliberation, as measured by the REI, best predicted clinically relevant traits (schizotypy) in a general non-clinical population.

Another way to test reasoning styles and biases is through syllogistic reasoning problems, and how much people use their prior beliefs in relation to logical processing in order to solve them. Syllogistic reasoning tasks typically involve presenting participants with two premises followed by a conclusion, and they have to assess if the conclusion is valid based on the two preceding premises. There are two aspects that are important about the syllogisms, their believability and their logical validity. In some instances, the premises are supportive of everyday knowledge and experiences, and so are very believable sounding, and so these are considered congruent (e.g. All birds have feathers. Robins are birds. Robins have feathers). In other cases, the premises are not very believable sounding, and these are considered incongruent (e.g. all mammals walk. Whales are mammals. Whales walk). The following is an example of a highly believable syllogism; “All flowers need water. Roses need water. Therefore, roses are flowers.” Although the two premises are highly believable, the conclusion does not actually follow from them in a logical way. People typically respond to that syllogism as being valid, which is thought to reflect an intuitive response (i.e. using beliefs rather than the structure of the problem). In contrast, the syllogism “No skyscrapers are wooden things. Some buildings are wooden things. Therefore, some buildings are not skyscrapers” is both highly believable and logically valid. This creates four different combinations of syllogism items: invalid-believable, valid-unbelievable, invalidunbelievable, and valid-believable. A ‘Belief Bias’ score is commonly created by subtracting the incongruent syllogism scores from the congruent syllogism scores (e.g. Klauer, Musch, & Naumer, 2000; Pennycook et al., 2013). A Belief Bias involves people refraining from allowing their prior experience and beliefs (i.e. their intuition) to affect their ability to judge the logical validity of the syllogism in order to resolve it correctly. However, people often incorrectly respond on the basis of the believability (i.e. they use their prior beliefs, or intuition) rather than based on its logical structure (i.e. they use deliberation), which results in higher Belief Bias scores (Evans, Barston, & Pollard, 1983; Evans, Handley, & Harper, 2001; Oakhill, Johnson-Laird, & Garnham, 1989; Pennycook et al., 2013; Roberts & Sykes, 2003; Shynkaruk & Thompson, 2006).

Dual Process Theory of Autism

The literature described above led to the idea of the ‘Dual Process Theory of Autism’, which predicts that people with autism and non-clinical people with high levels of autistic-like traits should show a cognitive style which involves a combination of higher deliberative and lower intuitive reasoning, compared to the typical reasoning responses seen in the general population. Thus the Dual Process Theory of Autism proposes that people with autism should show a reduced propensity to reason using an intuitive style, alongside a greater propensity to use a deliberative style for reasoning. This pattern of reasoning would be expected to result in group differences across tasks measuring intuition and deliberation, and since autistic-like traits are distributed across the wider population, the theory further predicts that the degree of autistic-like traits should also predict how much people engage in deliberative and intuitive reasoning (i.e. negative/positive correlations between the degree of autistic-like traits and intuitive/deliberative responses respectively). Based on the Dual Process Theory of Autism, people diagnosed with autism and people with higher autistic-like traits in the general population should also be less likely to show a Belief Bias, as well as other biased responses that reflect using prior knowledge and beliefs over structural information or other information about the current problem at hand.

We initially tested the ideas of the Dual Process Theory of Autism across two studies using different measures of reasoning in separate samples (Brosnan, Lewton & Ashwin, 2016). In study 1, we recruited 95 people (43 M; Mean age = 21) without a diagnosis of autism to investigate the relationship between the degree of autistic-like traits in a non-clinical sample and deliberative and intuitive reasoning. All participants completed the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001) to measure the degree of autistic-like traits, along with the REI self-report measure for deliberative (rationale) and intuitive (experiential) reasoning. The participants were split into 4 different groups based on their REI scores across both the intuitive and deliberative scales; a high deliberation/low intuition group, a high deliberation/high intuition group, a low deliberation/low intuition group, and a low deliberation/high intuition group. Results showed the group with a combination of high deliberation and low intuition scores had a significantly higher number of autistic-like traits compared to the group with a combination of high intuition and low deliberation. These results are consistent with the hypothesis that a higher number of autistic-like traits would relate to a pattern of reasoning characterised by high deliberation and low intuition (and opposite to the of schizotypy, Freeman et al., 2012 – see above).

We further tested the idea that autism is characterised by greater deliberation and reduced intuition in Study 2 (Brosnan, Lewton & Ashwin, 2016). For this study we recruited 17 males with autism (mean age = 18.4) and 18 males without autism as the control group (mean age = 19.5), with both groups matched on age. Intuition and deliberation were measured once again using the REI, as well as with the CRT task which includes questions that index intuitive and deliberative responding (see above). Results for the CRT revealed that the autism group had significantly more correct responses (which are presumed to reflect deliberative responses) and significantly fewer incorrect responses (specifically those which are presumed to reflect intuitive responses) compared to the control group. Furthermore, within-group analyses of the CRT scores revealed that the pattern of correct versus incorrect scores within the autism group showed a more extreme pattern than that seen within the control group. That is, the mean number of incorrect scores for those with autism were far lower compared to the mean number of correct responses, while the control group showed less extreme differences between their mean correct and incorrect scores. Together, this pattern of responding in the autism group is presumed to reflect both lower intuitive responding and higher deliberative responding compared to the controls. Results for the REI revealed that the autism group had significantly lower levels of self-reported intuitive scores and marginally significantly higher self-reported deliberative scores compared to the control group. These findings are consistent with other research showing less reliance on intuitive/experiential processing on adults on the autism spectrum (Gaeth et al., 2016; Levin et al., 208). Taken together, these results across two different studies and using different reasoning measures provides compelling evidence for the Dual Process Theory of Autism, which proposes that autism is characterised by reduced intuitive and enhanced deliberative reasoning (Brosnan & Ashwin, 2018; Brosnan et al., 2016).

However, the study by Brosnan et al. (2016) did not include a measure of general cognitive ability, in order to test cognitive ability in relation to reasoning and the degree of autistic-like traits (Study 1), and for comparison between the autism and control groups (Study 2). Since general cognitive ability has been argued within Dual Process theory to relate to deliberative, but not intuitive reasoning, the previous results may potentially be explained by differences in general cognitive ability in those with autism or in relation to the degree of autistic-like traits. A further study (Brosnan et al., 2017) was run in a sample of people with and without autism and including a measure of general cognitive ability, along with the CRT as an index of intuitive and deliberative reasoning and the AQ as a measure of autistic traits. According to the Dual Process Theory of Autism, the autism group should show a reduced number of incorrect responses (thought to index intuition) and a greater number of correct responses (thought to reflect deliberation) compared to controls, even when general cognitive ability was controlled for. We recruited 26 individuals with autism (15M; mean age = 18.3) and 22 individuals without autism as the control group (11M; mean age = 17.9). Neither the ratio of males and females nor the mean ages differed between the groups. A MANOVA was run on the CRT data with sex and general cognitive ability used as covariates and results revealed that the autism group made significantly fewer incorrect responses (presumed to reflect intuitive processing) compared to the control group, with no significant group differences were found for correct responses (presumed to reflect deliberative responses). Additionally, there were not any significant effects found for either of the covariates, which included general cognitive ability. The CRT data was then pooled together across both groups to increase the power, while controlling for sex and group. Correlation results on this larger sample revealed a significant negative correlation between the number of autistic-like traits (i.e. AQ scores) and number of incorrect responses (i.e. intuition), and a significant positive correlation between the number of autistic-like traits and correct responses (i.e. deliberation). No significant relationships were found between general cognitive ability and number of either correct or incorrect responses in the analyses. These results once again showed that a higher number of autistic-like traits was related to a pattern of reduced intuitive and enhanced deliberative processing, and that these results are not explained by general cognitive ability or by sex (Brosnan et al., 2017). In situations where people are given a problem to solve (e.g. A bat and a ball cost £1.10 in total. The bat costs a pound more than the ball. How much does the ball cost?), people who have higher autistic-like traits tend to be less likely to provide the more commonly given but incorrect answer (e.g. 10 pence), and are more likely to provide a correct response (e.g. 5 pence).

We further tested the Dual Process Theory of Autism by investigating the relationship between the degree of autism traits in a non-clinical sample and intuitive and deliberative processing as measured using a syllogistic reasoning task (Lewton, Ashwin & Brosnan, 2018). We also included the CRT in the study as a further measure of intuitive and deliberative reasoning, and the Raven's Advanced Progressive Matrices as a measure of general cognitive ability. We hypothesised that higher levels of autistic-like traits would be associated with reduced belief-bias based responses (presumed to reflect intuitive processing) and enhanced logic-based responses (presumed to reflect deliberative processing) when controlling for general cognitive ability. We further expected that general cognitive ability would relate to deliberative processing, but not intuitive processing. We recruited a total of 189 British adult participants aged between 18 and 62 years (103M; mean age = 27.3), with all the participants either in full-time education or full-time employment and none of the participants reporting a diagnosis of a psychiatric disorder. All participants completed the AQ (Baron-Cohen et al., 2001) as a measure of the degree of autistic-like traits, and the CRT and a syllogistic reasoning task (Kokis et al., 2002) in order to index intuitive and deliberative reasoning (measures explained above). Results with the CRT showed that a higher degree of autistic-like traits in the non-clinical sample related to reduced incorrect responses (reflecting intuitive reasoning) and greater correct responses (reflecting deliberative reasoning). In addition, a higher number of autistic-like traits related to greater accuracy on the incongruent syllogisms and a reduced Belief Bias score (incongruent – congruent syllogism responses), both of which are proposed to index deliberative reasoning. When people are given a syllogism for which beliefs and logic conflict, such as: "All flowers need water. Roses need water. Therefore, roses are flowers.", people who have higher autistic-like traits tend not to rely on beliefs and instead correctly judge that the conclusion is not logically valid. In contrast, people who have lower autistic-like traits tend to answer incorrectly, based on their beliefs. Together, the results using two different measures once again reveal findings consistent with the Dual Process Theory of Autism, with a higher degree of autistic-like traits related to greater deliberative and reduced intuitive reasoning. Together, the results indicate that high levels of autistic-like traits are associated with a greater tendency for deliberative (Type 2) processing to over-ride the initial intuitive (Type 1) processing.

Implications of the Dual Process Theory of Autism

Results with the CRT task revealed the autism group had reduced incorrect responses (thought to represent intuitive reasoning) and greater correct responses (thought to represent deliberative reasoning) compared to controls. Therefore, people with autism were more correct and showed less susceptibility to the typical reasoning biases causing which typically lead people to choose intuitive, but wrong, answers. The intuitive biases (including the Belief Bias) are thought to occur through the automatic use of rapid and effortless processes involved with intuition, as opposed to the more engaging and effortful deliberative processing. According to Kahneman (2011), the intuitive responses on the CRT that people in the general population more readily utilise can be viewed as ‘lazy thinking’. In contrast, autistic people have a propensity for not being lazy thinkers or cognitive misers (see Brosnan et al. 2016). From this viewpoint, the greater deliberation seen in autism and people with high autistic-like traits is best characterized as being ‘unbiased’, or less influenced by context. This view is consistent with the views of others that propose the characteristics of autism represent a different “style” of information processing, rather than a deficit (Frith, 1989; Happé, 1999). Since Dual Process theories are thought to reflect a style rather than strict ability, the Dual Process Theory of Autism proposes that autism involves a different style of reasoning and decision-making, rather than a reasoning deficit per se. This different style of reasoning is biased towards deliberative responses, and is less susceptible to potentially erroneous biases (Brosnan & Ashwin, 2018; Brosnan et al. 2016, 2017; De Martino et al. 2008; Shah et al., 2016). In experiments involving participants with and without autism and measuring intuitive and deliberative responses (e.g. the REI or the CRT), this type of reasoning style in autism is predicted to show group differences, with the autism group showing reduced intuitive responding alongside greater deliberative responding. This may be in the form of having fewer incorrect and more correct answers or scoring lower on items measuring intuitive cognitions and behaviours, and higher on items measuring deliberative cognitions and behaviours. When measuring the degree of autistic-like traits (in either nonclinical or autistic samples), higher levels of autistic-like traits is predicted to be positively related to higher deliberative responding and negatively related to intuitive responding, as measured by questionnaire items, number of correct answers, or use of contextual/item information etc.

Reduced intuition in autism might be beneficial in some situations, but more detrimental in other contexts. It is argued that effective social communication and interaction is typically supported by the more rapid, automatic and effortless intuitive processing that helps to promote prosocial behaviour, such as cooperation (Rand et al. 2012). Despite the susceptibility to bias and error inherent to intuitive processing and the benefits of deliberative processing, intuition can be invaluable, and even necessary, in many instances requiring quick reasoning and decision making. This is especially true during dynamic social interactions in real life situations. Many of the social and emotional processes supporting prosocial behaviour are associated with intuitive processing because they involve rapidly changing situations requiring quick judgments and responses (Evans and Stanovich 2013; Rand et al. 2012). A reasoning bias characterized by reduced intuition may underlie the social difficulties consistently seen in autism. Consistent with this idea, Mendelson et al. (2016)

suggested that a slower, inefficient, social information processing speed specifically underlies many of the social deficits commonly seen in autism, such as the ability to develop and maintain friendships. As noted by Darius (2002: p. 25): “There is no such thing as adequate delayed social reactions. One is either quick enough to keep up, or one is weird and socially disabled.” Rapidly and automatically extracting emotional information from social environments is argued to be an intuitive process that feeds “downstream” empathy processes and related social-emotional functioning (Kahneman 2011). Thus, the unbiased use of deliberation proposed by the Dual Process Theory of Autism may relate to the social-emotional weaknesses which form part of the diagnostic criteria for autism. The “gut feelings” that can produce a rapid and automatic sense of danger about someone else are part of the intuitive processes, and can produce behaviours that help to minimise the risk of being bullied, exploited, or harmed (e.g. see Maïano et al., 2016). Deliberative processing is less likely to produce this automatic gut feeling about potentially dangerous individuals, and instead might even result in greater data gathering about them and, therefore, even more social interaction. This scenario could result in greater vulnerability to social harm in autism.

A bias in reasoning and decision-making in autism characterised by greater deliberation and reduced intuition could have important academic implications, such as for those attending higher education. Students with autism attending college and university might need support to facilitate their learning and assessment based on their reasoning style, such as extra time during exam sessions and for completing and handing in assignments, in order to accommodate greater deliberation and longer times to make decisions. They may also benefit from lectures being filmed so they can watch and think about them over a longer period of time, as they may not intuitively understand everything during the lecture period. This would allow them to personalise the speed of processing of the lecture material to suit their thinking style. Slowing down information to allow longer processing has been shown to help people with autism. For example, physically slowing down incoming social-emotional information for children with autism has been shown to enhance the ability to recognise the emotions of others and to produce greater social-emotional imitation (Laine et al., 2011; Tardif et al. 2007). Therefore, the cognitive style of those with autism might not be suited to learning and decisions-making within many typical forms of university working and assessment situations, which often require fast and dynamic information processing. These include such common procedures as group work assignments, oral assessments, viva defences, and unseen exams etc. According to the Dual Process Theory of Autism, support designed to facilitate a more deliberative reasoning style within these types of situations would help the performance and success of students with autism at higher education, where they often struggle compared to other students.

The Dual Process Theory of Autism also proposes a relative bias towards deliberative processing, which may also provide an account of the strengths associated with autism in the literature such as pattern recognition and attention to detail (e.g., Baron-Cohen et al. 2009; Happé & Vital, 2009). Such capabilities are often highly visual-spatial in nature and have been found to correlate with self-report and behavioural assessments of deliberative processing, such as the CRT (Brosnan et al. 2014). It seems plausible to speculate that a greater attention to detail and appreciation of patterns within incoming data (e.g., visual-spatial information) would require more conscious processing resources (e.g. working memory). The propensity for greater focus and thinking about excessive details in autism may underpin the tendency for deliberative processing to override the rapid and automatic intuitive thinking, which is faster but also more prone to bias and errors. Such strengths in autism around enhanced focus, greater processing of details and error reduction has been argued to be advantageous in a wide array of employment context such as computer programmers, software design, communications and networking, engineering design, equipment design, mechanics, research, mechanics repair, advanced machines assembly, lab technicians, web design, video game design, app designs, accounting, chemistry, engineering, statistics, computational art and animation (Grundwag et al., 2017).

Based on the differences in intuitive and deliberative reasoning and responding in autism, there are certain adaptations and support mechanisms within work environments that could help facilitate performance and success for autistic people at work. This is important as recent reports show that only 16% of autistic adults are in full-time employment, despite 77% of autistic adults saying they want to work (APPGA, 2017). There are relevant issues for both the initial steps in the hiring practices, as well as for the policies and procedures utilised within companies once autistic people are employed. In terms of the initial steps in gaining employment, there are often questions on applications and in interviews where people intuitively respond in certain ways to positively suit the situation. For example, a common question in interviews is “What is your greatest weakness?” People in the general population often intuitively know to choose a trait about themselves that displays minimal negativity, and which might even put a spin on the situation to reflect a positive attribute. This might be that their greatest weakness is being overly perfectionistic, which on the surface conveys about a weak personality trait in answer to what was asked, but when reading between the lines it also conveys that the candidate is highly concerned about performing to a very high level of ability i.e. about being perfect in their work. Instead, autistic people might deliberate for a lengthy period when asked this type of question, which during an interview process might actually produce a negative impression about them to the interviewers (e.g. perhaps that they are having to think amongst a plethora of weaknesses towards an answer). Even if a candidate with autism were to consciously deliberate at length about a potential answer to that question, it still might not bring a person closer to a suitable answer in that type of situation. In fact, it might serve to confuse the candidate further by having to consider numerous different potential answers in a highly pressurised situation, and could actually be more likely to lead them to a poor choice in answer to the question. For example, they might be overly honest and say they are always late with assignments, which would likely cost them the potential job opportunity. Anecdotally, when an autistic interviewee was asked 'where they would like to be in 5 years-time?', after lengthy deliberation they answered: "at home".

Some companies have now started giving alternatives to face-to-face interview processes for potential employees with autism, with the initial steps involving written correspondence with the company in their own time-scale. For example, using Social Media (such as Facebook) allows the time for autistic people time to reflect upon their answers before sharing them (Brosnan & Gavin, 2015). This is important as a cost-benefit study of employers in companies of people with autism found that they reported no costs to employing workers with autism, only benefits (Scott et al, 2017). Perhaps reducing the amount of decisions to be made during meetings would be beneficial, in order to allow time for those with autism to deliberate on the information and ideas towards making decisions. Similarly, accommodations could be made within practice and policies of companies to suit a less intuitive and more deliberative reasoning style, for example by reducing time pressure conditions and decision-making situations as much as possible.

Limitations

However, not all the results in the studies outlined above were consistent with predictions made by the Dual Process Theory of Autism. While reduced incorrect/intuitive responses were consistently found throughout our research in those with autism compared to controls and in relation to higher degrees of autistic-like traits, the findings did not always show enhanced correct/deliberative responses in those with autism or in relation to higher degrees of autistic-like traits. For example, in the study by Brosnan et al. (2017) no group differences were found for correct/deliberative responses using the CRT, although the rest of the findings in that study were consistent with the Dual Process Theory of Autism. Furthermore, the group differences for rationale responses on the REI in the study by Brosnan et al. (2016) were only marginally significant. Together, these non-significant findings for greater deliberative/rationale responses in autism are in line with previous reports of a lack of group differences in rationale/deliberative responses in the study of heuristic reasoning in adolescents with autism by Morsanyi et al. (2010). One possible explanation why greater deliberative responses in autism are not always found in reasoning studies is there are weaker effect sizes when comparing deliberative compared to intuitive measures. In the study by Brosnan et al. (2017) there were no group differences found for correct responses in the CRT, which is thought to measure deliberative processes. However, when the data for both groups was pooled together to increase power, significant effects were then found that revealed a higher degree of autistic-like traits was related to higher correct/deliberative responses on the CRT. So it may be that sufficiently large numbers of participants and data are needed to generate enough power for statistical effects to be evident in autism when investigating differences/relationships involving deliberative measures, while there are greater effect sizes for differences in intuitive responding in people with autism versus controls.

It may also be that autism and higher-levels of autistic-like traits relate to the propensity to engage in deliberative processing, rather than the ability to engage in deliberative processing. It seems feasible that autistic-like traits (which autistic people are high in) impact upon the propensity to engage in deliberative processing and cognitive ability impact upon the ability to obtain the correct response (Brosnan et al., 2017; Lewton et al., 2018). Relatedly, an important consideration is the extent to which measures such as the CRT assess intuition, given that intuitive responses are incorrect (albeit in a pre-specified way).

Pennycook et al. (2015) argue that the CRT may assess the propensity to engage in intuitive processing, rather than being a measure intuitive ability.

There have also been some issues raised about Dual Process theories, which have questioned their effectiveness to explain results and ideas about reasoning and the underlying mechanisms, which will be briefly discussed. One issue concerns whether there are actually two different processes involved in reasoning, or just one process that is implemented at different points in time during information processing (Evans & Stanovich, 2013; Osman, 2013; Melnikoff & Bargh, 2018). In fact, some believe that a single theory of reasoning may be sufficient to explain the research findings (Kruglanski & Gigerenzer, 2011; Osman, 2013). There is evidence that intuitive processes can sometimes be slow, and deliberative processes can sometimes be fast (Trippas et al., 2017), and also some research has reported that intuitive processes can be correct and deliberative processes can be incorrect (Pennycook et al., 2018). These findings question some of the factors typically used to separate intuitive from deliberative processing and provide support for the Dual Process idea. However, others contend that factors such as speed and accuracy are related to each other, but that they are not necessarily central factors for differentiating between intuitive and deliberative processing (Evan & Stanovich, 2013; Melnikoff & Bargh, 2018).

The issue of whether there are one or two reasoning systems has implications for the Dual Process Theory of Autism, which is proposed based upon the idea about there being two separate systems, one for intuition and one for deliberation. Since people with ASD often take longer to respond than controls in general on different types of experimental tasks and when making decisions (e.g. Baisch et al., 2017; Luke et al., 2012), if there was only one system then longer response times in autism might create the impression of greater deliberative responding, but might simply reflect longer latencies for information processing in general. This general tendency for longer responses in ASD would make it more difficult for them to respond intuitively and create a bias towards longer and more accurate processes in some contexts. However, the longer responding in autism might not necessarily reflect greater deliberative processes or the over-riding of intuition by deliberation, but instead might simply be a consequence of differences in general information processing. This could be a potentially important line of further research to test the Dual Process Theory of Autism, particularly given the issues about the default interventionist view within the reasoning field, which states that intuitive responses are the default response unless acted upon by deliberative processes. These issues include about how conflict detection occurs between the two systems, the possible underlying mechanisms, and contrary evidence such as findings where people who provide an intuitive response appearing to detect conflict (De Neys, 2012; De Neys & Bonnefon, 2013; Evans & Stanovich, 2013; Melnikoff & Bargh, 2018; Pennycook et al., 2018).

Questions and future directions

While a strong line of evidence now supports the predictions made by the Dual Process Theory of Autism, the nature of the mechanisms involved and how they are different in those with autism remains unclear, as well as about how the pattern of strengths and weaknesses in reasoning tie in with other theories of autism (e.g. key two-factor models). Whilst empathising has been found to relate to traditional personality measures of agreeableness, systemising has no such correlates (Nettle, 2007). Since previous research has shown associations between systemising and deliberative responses (Brosnan et al., 2014), it may be that systemising/mechanistic processing shares a strong overlap with deliberation. Or that a strong drive to systemise may involve a higher tendency for conscious deliberative thought in order to analyse the details and detect consistencies and patterns. While the Dual Process Theory of Autism proposes that autism and high levels of autistic-like traits involve a propensity to engage in more deliberative processing, this does not necessarily mean the deliberative processing will necessarily reflect higher ability, i.e. that greater deliberative processing will always produce better reasoning ability and outcomes. Since reasoning 'abilities' are more closely related to measures of general cognitive ability, an interesting question is whether the difference in reasoning style would be evident across the entire autism spectrum, including those with intellectual disabilities. Much of the research in autism has been carried out with people who do not have an intellectual disability, despite intellectual disability being a highly co-occurring condition with autism. We would predict that those with autism and intellectual disability would have a propensity to engage in deliberative processing over intuition, but the effectiveness of such processing would be influenced by further factors, such as impaired general cognitive ability. Similarly, the vast majority of research has been conducted upon autistic males, with research lacking on autistic females. Whilst we would predict that autistic females will show the same pattern of a tendency to engage in deliberative processing according to the Dual Process Theory of Autism, this needs to be empirically tested.

The Dual Process Theory of Autism also proposes that autonomous and rapid intuitive processing is either impaired or is not spontaneously utilised in autism, but it does not directly specify difficulties in social-emotional processing. Instead, many types of social-emotional processing represent very salient examples of intuitive processing, or processes that rely on strong intuition. Social heuristics are underpinned by intuition (Rand et al., 2012) which promote cooperation and pro-social behaviour. Thus, the Dual Process Theory of Autism proposes that deficits in engaging in intuitive processing result in decreased application of social heuristics. This may relate to a perceived lack of agreeableness, which has been found to correlate with empathising (Nettle, 2007). Thus a bias away from intuitive processing may have consequences which include difficulties with rapid emotion processing and a bias away from pro-social behaviour – but not a deficit in empathy *per se* (although emotion recognition tasks are often used as an index of empathising). This idea is distinct from the two-factor models, which explicitly propose a deficit in the empathising/mentalising mechanisms. However, while other two-factor models have trouble explaining patterns of strengths and weaknesses and intact abilities *within* social-emotional processing for those with autism, the Dual Process Theory of Autism predicts that greater difficulties should emerge in autism for faster and more automatic social-emotional processes that involve higher intuition, and that fewer difficulties should be evident for social-emotional processes requiring less intuition. Similarly, not all systemising/mechanistic processing requires strong deliberation, which may also help explain similar profiles of strengths and weaknesses within non-social processing in autism. Future research needs to explore these distinctions between theories related to the involvement of deliberation and intuition in various social and non-social abilities in autism.

Many questions remain concerning the underlying mechanisms related to the reasoning differences in autism, as there are different potential causes for these differences. One possibility is that the mechanisms for intuitive reasoning are impaired in autism, resulting in deliberation being the default and dominant form of reasoning. If the intuitive mechanisms are impaired, this would lead to pervasive deficits in any processing requiring rapid and unconscious processing across different domains and functioning, such that even if someone with autism tried to utilise intuitive processing, they would have difficulties in doing this. An alternative possibility is that the mechanisms for intuitive processing are intact, but that autistic people do not typically or spontaneously utilise that specific style of reasoning, or that the information processing mechanisms they typically use do not easily relate to or involve intuitive mechanisms. This scenario would differ to that above in that autistic people would be able to utilise intuitive reasoning in some instances, if necessary, because the basic mechanisms would be intact. In both of these scenarios above deliberative processing would dominate within reasoning due to the dysfunction of the typical intuitive mechanisms. In contrast, the reasoning differences in autism could reflect dysfunction of the mechanisms for deliberation. This could involve either hyper-functioning of these mechanisms, or an inability to regulate the deliberative mechanisms appropriately. This dysfunction could occur alongside typical functioning of intuition, but in this scenario the mechanisms for intuition would be regularly 'over-ridden' by the deliberative processes which would dominate reasoning. A further possibility is that autism could involve dysfunction to both intuitive and deliberative mechanisms simultaneously, with differences occurring in both types of processing affecting information processing and producing the reasoning style outlined by the Dual Process Theory of Autism. Finally, there may be a problem in autism with automatizing behaviour, that is, the flexibility in transitioning between deliberation and intuition.

If a difficulty resides in automatizing social heuristics (intuitive processing), one possibility is that autistic people engage in social algorithms (deliberative processing). An algorithm is a finite series of steps used to reach a solution, such as a recipe for cooking or undertaking arithmetic. In such situations, a likely outcome is highly predictable. Many social-world scenarios, however, incorporate elements of chance, time-accuracy trade-offs and using approximation. Despite this, Christian and Griffiths (2016) propose some algorithms to live by. For example, they discuss the secretary problem; if you advertise for a secretary, how many people do you interview to hire the best possible candidate? There are rules such as you can only interview one at a time, and you must offer the job immediately when you think you have made the right decision. The issue is not which option to pick, but how many options to consider. The algorithm applied for an optimum solution in this scenario is the 'look before you leap rule', which states that you interview the first 37% of applicants without offering them the job, then offer the job to the first applicant who is better than those you have previously seen. Christian and Griffiths argue that such an algorithm can extend to other aspects of life, such as dating. This ‘optimal stopping’ is concerned with choosing the time to take a given action. Because there is always a time cost for people, the authors argue that the flow of time turns all decision making into optimal stopping. We saw with the beads task earlier, that those with autism stop gathering data before making a decision significantly later than non-autistic people. Thus it may be the case that explicitly considering optimal algorithms will be useful for autistic people if they are utilising social algorithms in situations when people are typically utilising social heuristics.

References

All Party Parliamentary Group on Autism (2017). *Autism and Education in England*. London, UK.

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition. Arlington, VA, American Psychiatric Association.

Auyeung, B., Baron-Cohen, S., Ashwin, E., Knickmeyer, R., Taylor, K., and Hackett, G. (2009). Fetal testosterone and autistic traits. *British Journal of Psychology*, 100, 1–22.

Badcock, C., & Crespi, B. (2008). Battle of the sexes may set the brain. *Nature*, 454(7208), 1054–1055.

Baio J, Wiggins L, Christensen DL, et al. (2018). Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years - Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014. *Morbidity and Mortality Weekly Reports; Surveillance Summaries*, 67, 1-23.

Baisch, B., Cai, S., Li, Z., & Pinheiro, V. (2017). Reaction Time of Children with and without Autistic Spectrum Disorders. *Open Journal of Medical Psychology*, 6, 166-178

Baron-Cohen, S. (1990). Autism: a specific cognitive disorder of “mind-blindness”. *International Review of Psychiatry*, 2, 81-90.

Baron-Cohen, S. (1995). *Mindblindness: an essay on autism and theory of mind*. Boston: MIT Press/Bradford Books.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, 6, 248-254.

Baron-Cohen, S. (2003). *The Essential Difference: male and female brain*. London: Penguin.

Baron-Cohen S. (2009). Autism: the empathizing-systemizing (E-S) theory. *Annals of the New York Academy of Sciences*, 1156, 68-80.

Baron-Cohen, S. & Wheelwright, C. (2004). The Empathy Quotient (EQ). An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, 34, 163–175.

Baron-Cohen, S., Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2009). Talent in autism: hyper-systemizing, hyperattention to detail and sensory hypersensitivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364, 1377–1383.

Baron-Cohen, S., Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2011). *The paradox of autism: why does disability sometimes give rise to talent?* In N. Kapur (Ed.), The Paradoxical Brain (pp. 274-288). Cambridge: Cambridge University Press.

Baron-Cohen, S., Knickmeyer, R. C., Belmonte, M. K. (2005). Sex differences in the brain: implications for explaining autism. *Science*, 310(5749), 819-823.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, 21, 37–46.

Baron-Cohen, S., Lombardo, M.V., Auyeung, B., Ashwin, E., Chakrabarti, B., Knickmeyer, R. (2011). Why are autism spectrum conditions more prevalent in males? *PLoS Biology*, 9(6), e1001081.

Baron-Cohen, S., Tager-Flusberg, H. & Cohen, D. J. (1993). *Understanding Other Minds: Perspectives from developmental social neuroscience*. Oxford: Oxford University Press.

Baron-Cohen, S., Tager-Flusberg, H. & Cohen, D. J. (2000). *Understanding Other Minds: Perspectives from developmental social neuroscience* (2nd ed.). Oxford: Oxford University Press.

Baron-Cohen, S., Lombardo, M., & Tager-Flusberg, H. (2013). *Understanding Other Minds: Perspectives from developmental social neuroscience* (3rd ed.). Oxford: Oxford University Press.

Baron-Cohen, S., Richler, J., Disarya, B., et al. (2003). The Systemising Quotient (SQ): an investigation of adults with Asperger Syndrome or High Functioning Autism and normal sex differences. *Philosophical Transactions of the Royal Society*, 358: 361–74.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001a). The ''Reading the Mind in the Eyes'' test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry*, 42, 241–251.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001b). The Autism-Spectrum Quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders,* 31, 5–17.

Brosnan, M., Ashwin, C., & Lewton, M. (2017). Brief Report: Intuitive and Reflective Reasoning in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 47(8), 2595-2601.

Brosnan, M., Ashwin, C., Walker, I., & Donaghue, J. (2010). Can an 'Extreme Female Brain' be characterised in terms of psychosis? *Personality and Individual Differences*, 49(7), 738-743.

Brosnan, M., Ashwin, C. (2018). *Reasoning on the Autism Spectrum*. In *Encyclopedia of Autism Spectrum Disorders* (pp. 1-7). Springer

Brosnan, M., Ashwin, C., Gamble, T. (2013). Greater empathizing and reduced systemizing in people who show a jumping to conclusions bias in the general population: implications for psychosis. *Psychosis*, 5(1), 71-81.

Brosnan, M., Chapman, E., Ashwin, C. (2014) Adolescents with Autism Spectrum Disorder Show a Circumspect Reasoning Bias Rather than ‘Jumping-to-Conclusions’. *Journal of Autism and Developmental Disorders*, 44, 513-520.

Brosnan, M. and Gavin, J. (2015) *Are “Friends” Electric? Why Those with an Autism Spectrum Disorder (ASD) Thrive in Online Cultures but Suffer in Offline Cultures*. In Larry D. Rosen, Nancy A. Cheever, L. Mark Carrier (eds) The Wiley Handbook of Psychology, Technology, and Society. Blackwell: London.

Brosnan, M. J., Gwilliam, L. R., & Walker, I. (2012). Brief report: the relationship between visual acuity, the embedded figures test and systemizing in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 42(11), 2491-2497.

Brosnan, M., Hollinworth, M., Antoniadou, K., & Lewton, M. (2014). Is Empathizing intuitive and Systemizing deliberative? *Personality and Individual Differences*, 66, 39-43.

Brosnan, M., Lewton, M., Ashwin, C. (2016). Reasoning on the Autism Spectrum: A Dual Process Theory Account. *Journal of Autism and Developmental Disorders*, 46, 2115-2125.

Buescher, A. V. S., Cidav, Z., Knapp, M., & Mandell, D. S. (2014). Costs of Autism Spectrum Disorders in the United Kingdom and the United States. *JAMA Pediatrics, 1*68(8), 721-728.

Cacioppo, J. T., Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology,* 42, 116.

Christian, B., & Griffiths, T. (2016). *Algorithms to live by*. Harper Collins: London.

Constantino, J. N., & Todd, R. D. (2003). Autistic traits in the general population: a twin study. *Archives of General Psychiatry*, 60(5), 524-530

Crespi, B., & Badcock, C. (2008) Psychosis and autism as diametrical disorders of the social brain. *The Behavioral and Brain Sciences*, 31(3), 241-61.

Darius. (2002). Darius’s Essay. In D. Prince-Hughes (ed.), *Aquamarine Blue 5: Personal stories of college students with autism* (pp. 9–42). Athens, OH: Swallow Press.

De Martino, B., Harrison, N. A., Knafo, S., Bird, G., Dolan, R. J. (2008). Explaining enhanced logical consistency during decision making in autism. *Journal of Neuroscience*, 28(42), 10746-50.

De Neys, W. (2012). Bias and conflict: A case for logical intuitions. *Perspectives on Psychological Science*, 7, 28-38.

De Neys, W., & Bonnefon, J. F. (2012). The ‘whys’ and ‘whens’ of individual differences in thinking biases. *Trends in Cognitive Sciences*, 17(4), 172-178.

Epstein, S., Pacini, R., Denes-Raj, V., Heier, H. (1996). Individual differences in intuitive–experiential and analytical–rational thinking styles. *Journal of Personality and Social Psychology, 71*, 390.

Evans, J. S., Barston, J. L., & Pollard, P. (1983) On the conflict between logic and belief in syllogistic reasoning. *Memory and Cognition*, 11(3), 295-306.

Evans, J. S.., & Curtis-Holmes, J. (2005). Rapid responding increases belief bias: Evidence for the dual-process theory of reasoning. *Thinking & Reasoning,* 11*,* 382–389.

Evans, J. S., & Frankish, K. (2009). *In two minds: Dual processes and beyond.* Oxford: Oxford University Press.

Evans, J. S., Handley, J. S., & Harper, C. N. J. (2001). Necessity, Possibility and Belief: A Study of Syllogistic Reasoning. *Quarterly Journal of Experimental Psychology*. 54(3), 935–958.

Evans, J. S., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition: Advancing the Debate. *Perspectives in Psychological Science*, 8(3), 223-241.

Frith, U. (1989). *Autism: Explaining the enigma*. Oxford: Basil Blackwell.

Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives*, 19 (4), 25-42.

Freeman, D. (2007). Suspicious Minds: the psychology of persecutory delusions. *Clinical Psychology Review*, 4, 425–457.

Freeman, D., Evans, N., Lister, R. (2012). Gut feelings, deliberative thought, and paranoid ideation: A study of experiential and rational reasoning. *Psychiatry Research, 197*, 119–122.

Gaeth, G. J., Levin, I. P., Jain, G., & Burke, E. V. (2016), Toward understanding everyday decision making by adults across the autism spectrum. *Judgment and Decision Making*, 11, 537-546.

Goldstein, G., Johnson, C. R., Minshew, N. J. (2001) Attentional processes in autism. *Journal of Autism and Developmental Disorders*, 31, 433-440.

Grundwag, C., Nordfors, D., & Yirmiya, N. (2017, November 25). “COOLABILITIES” – ENHANCED ABILITIES IN DISABLING CONDITIONS. https://doi.org/10.31235/osf.io/stgd4.

Happé, F. (1999). Autism: cognitive deficit or cognitive style? *Trends in Cognitive Science*, 3(6), 216-222.

Happé, F., & Frith, U. (2006). The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 36(1), 5-25.

Happé, F., & Vital, P. (2009). What aspects of autism predispose to talent? *Philosophical Transactions of the Royal Society of London: B Biological Sciences*, 364(1522), 1369–1375.

Holyoak, K. J., Morrison, R. G. (2012). *The Oxford Handbook of Thinking and Reasoning*. Oxford: Oxford University Press.

Jolliffe T, Baron-Cohen S. (1997). Are people with autism or Asperger's Syndrome faster than normal on the Embedded Figures Task? *Journal of Child Psychology and Psychiatry*, 38, 527-534.

Kahneman, D. (2011). *Thinking, fast and slow*. London: Penguin.

Kanne, S. M., Abbacchi, A. M., Constantino, J. N. (2009). Multi-informant Ratings of Psychiatric Symptom Severity in Children with Autism Spectrum Disorders: the Importance of Environmental Context. *Journal of Autism and Developmental Disorders*, 39(6), 856–864.

Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., & Pellicano, E. (2016). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism*, 20(4), 442-62.

Klauer, K. C., Musch, J., & Naumer, B. (2000). On belief bias in syllogistic reasoning. *Psychological Review*, 107(4), 852-884.

Kokis, J. V., Macpherson, R., Toplak, M. E., West, R. F., & Stanovich, K. E. (2002). Heuristic and analytic processing: Age trends and associations with cognitive ability and cognitive styles. *Journal of Experimental Child Psychology*, 83, 26–52.

Kruglanski, A. W., & Gigerenzer, G. (2011). Intuitive and deliberatejudgments are based on common principles. *Psychological Review*, 118, 97.

Lainé, F., Rauzy, S., Tardif, C., & Gepner, B. (2011). Slowing down the presentation of facial and body movements enhances imitation performance in children with severe autism. *Journal of Autism and Developmental Disorders*, 41(8), 983-996.

Langdon, R., Ward, P.B., Coltheart, M. (2008). Reasoning anomalies associated with delusions in schizophrenia. *Schizophrenia Bulletin*, 36, 321–330.

Larson, F. V., Lai, M. C., Wagner, A. P., MRC AIMS Consortium, Baron-Cohen, S., & Holland, A. J. (2015). Testing the ‘Extreme Female Brain’ Theory of Psychosis in Adults with Autism Spectrum Disorder with or without Co-Morbid Psychosis. *PLoS ONE*, 10(6), e0128102.

Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathising and systemising in adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 34(3), 301-310.

Levin, I. P., Gaeth, G. J., Levin, A. M., & Burke, E. (2019). *Decision making processes of* *high-functioning adults on the autism spectrum*. In K. Morsanyi & R. Byrne (Eds.), Thinking and Reasoning in Autism. London: Psychology Press/Routledge.

Lewton., L, Ashwin., C, & Brosnan, M. (2018). Syllogistic reasoning reveals reduced bias in people with higher autistic-like traits from the general population. *Autism*. Advanced online publication. https://doi.org/10.1177/1362361318808779

Luke, L., Clare, I. C., Ring, H., Redley, M., & Watson, P. (2012). Decision-making difficulties experienced by adults with autism spectrum conditions. *Autism*, 16(6), 612-621.

Maïano, C., Normand, C. L., Salvas, M. C., Moullec, G., Aimé, A. (2016). Prevalence of School Bullying Among Youth with Autism Spectrum Disorders: A Systematic Review and Meta-Analysis. *Autism Research*, 9(6), 601-615.

Melnikoff, D. E., Bargh, J. A. (2018). The Mythical Number Two. *Trends in Cognitive Science*, 22(4), 280-293.

Mendelson, J. L., Gates, J. A., & Lerner, M. D. (2016). Friendship in school-age boys with autism spectrum disorders: A meta-analytic summary and developmental, process-based model. *Psychological Bulletin*, 142(6), 601-622.

Minshew, N. J., Goldstein, G., & Siegel, D. J. (1997). Neuropsychologic functioning in autism: profile of a complex information processing disorder. *Journal of the International Neuropsychological Society*, 3(4), 303-316.

Morsanyi, K., Handley, S. J., & Evans, J.S.B.T. (2010). Decontextualised minds: Adolescents with autism are less susceptible to the conjunction fallacy than typically developing adolescents. *Journal of Autism and Developmental Disorders*, 40, 1378–1388.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., & Burack, J. A. (2006). Enhanced perceptual functioning in autism: An update and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, 36, 27–43.

Nettle, D. (2007). Empathizing and systemizing: What are they, and what do they contribute to our understanding of psychological sex differences? *British Journal of Psychology*, 98, 237–255

Oakhill, J., Johnson-Laird, P. N., Garnham, A. (1989). Believability and syllogistic reasoning. *Cognition*. 31(2), 117-140.

O'Riordan, M., Plaisted, K., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 719–730.

Osman, M. (2013). A Case Study: Dual-Process Theories of Higher Cognition-Commentary on Evans & Stanovich (2013). *Perspectives on Psychological Science*, 8(3), 248-252.

Ozonoff, S., Pennington, B., & Rogers, S. (1991). Executive function deficits in high-functioning autistic children: relationship to theory of mind. *Journal of Child*

Psychology and Psychiatry, 32, 1081-1106.

Pacini, R., & Epstein, S. (1999). The relation of rational and experiential information processing styles to personality, basic beliefs, and the ratio-bias phenomenon. *Journal of Personality and Social Psychology, 76*, 972.

Pennycook, G., Cheyne, J. A, Koehler, D. J, & Fugelsang, J. A. (2013). Belief bias during reasoning among religious believers and skeptics. *Psychonomic Bulletin and Review*, 20(4), 806-811.

Pennycook, G., Cheyne, J. A., Koehler, D. J., & Fugelsang, J. A. (2015). Is the cognitive reflection test a measure of both reflection and intuition? *Behavior Research Methods*, 48, 341–348.

Pennycook, G., Neys, W., Evans., J. S. B. T, Stanovich., K. E, & Thompson., V. A. (2018). The Mythical Dual-Process Typology. *Trends in Cognitive Science*, 22(8), 667-668.

Plaisted K. C., Dobler, V., Bell, S., & Davis, G. (2006). The microgenesis of global perception in autism. *Journal of Autism and Developmental Disorders*, 36, 107-116.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced visual search for a conjunctive target in autism: a research note. *Journal of Child Psychology and Psychiatry*, 39(5), 777-783.

Plomin, R., Haworth, C. M., & Davis, O. S. (2009) Common disorders are quantitative traits. *Nature Review Genetics,* 10(12), 872-878.

Posserud, M. B., Lundervold, A. J., & Gillberg, C. (2006). Autistic features in a total population of 7-9-year-old children assessed by the ASSQ (Autism Spectrum Screening Questionnaire). *Journal of Child Psychology and Psychiatry*, 47, 167-175.

Premack, D., & Woodruff, G. (1978). Does the Chimpanzee Have a Theory of Mind? *Behavioral and Brain Sciences*, 4, 515-526.

Rand, D. G., Greene, J. D., & Nowak, M. A. (2012). Spontaneous giving and calculated greed. *Nature*. 489(7416), 427-430.

Roberts, M. J., Sykes, E. D. (2003). Belief bias and relational reasoning. *Quarterly Journal of Experimental Psychology A. Human Experimental Psychology*, 56(1), 131-153.

Russell, J. (1997). *Autism as an Executive Disorder*. Oxford: Oxford University Press.

Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., Baron-Cohen, S. (2015). Measuring autistic traits in the general population: a systematic review of the Autism-Spectrum Quotient (AQ) in a nonclinical population sample of 6,900 typical adult males and females. *Molecular Autism*, 6, 2.

Scott, M., Jacob, A., Hendrie, D., Parsons, R., Girdler, S., Falkmer, T., Falkmer, M. (2017). Employers' perception of the costs and the benefits of hiring individuals with autism spectrum disorder in open employment in Australia. *PLoS ONE*, 12(5), e0177607.

Shah, P., Catmur, C., & Bird, G. (2016). Emotional decision-making in autism spectrum disorder: The roles of interoception and alexithymia. *Molecular Autism*, 7, 43.

Singleton, C.J., Ashwin, C. & Brosnan, M. (submitted). *The Dual Process Theory of Autism, Systemizing and formal logical reasoning*.

Shynkaruk, J. M., & Thompson, V. A. (2006). Confidence and accuracy in deductive reasoning. *Memory and Cognition*, 34(3), 619-32.

Tardif, C., Lainé, F., Rodriguez, M., Gepner, B. (2007). Slowing down presentation of facial movements and vocal sounds enhances facial expression recognition and induces facial–vocal imitation in children with autism. *Journal of Autism and Developmental Disorders, 37*, 1469–1484.

Trippas, D., Thompson., V., & Handley, S. J. (2017). When fast logic meets slow belief: Evidence for a parallel-processing model of belief bias. *Memory & Cognition*, 45(4), 539–552.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, 211, 453–458.

Williams, J. G., Higgins, J. P., Brayne, C. E. (2006) Systematic review of prevalence studies of autism spectrum disorders. *Archives of Disease in Childhood*, 91(1), 8-15.

Wing, L. (1988). *The Continuum of Autistic Characteristics*. In: Schopler, E., Mesibov, G. B. (eds.) Diagnosis and Assessment in Autism. Current Issues in Autism. Springer, Boston, MA.

Winter, M (2003). *Asperger Syndrome: What Teachers Need to Know*. London: Jessica Kingsley Publishers.